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**The role of sleep in the consolidation of novel words in English as a foreign
language**

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Abstract

The main aim of this research was to investigate the role of sleep and frequency of exposure in the consolidation of novel words in English as a foreign language (FL). Twenty advanced adult speakers of English (FL) were presented with 20 novel words in English, which were divided into two sets of 10 items. Half of the participants were exposed to the words in a single-training session and the other half in a double-training session. Participants learned the first set of words and had a full night's sleep before learning the second set. The first testing session took place immediately after the second training session and involved categorizing each novel word into living or nonliving entities. A week later, participants were required to take the same test again without the mediation of further training. The experiment showed a significant difference between consolidated and unconsolidated newly learned on day 2, with unconsolidated novel words showing an advantage over consolidated items. However, in the second test, performed a week later, there was no difference between the two sets of words. The comparison between the tests conducted on day 2 and day 8 showed that participants performed significantly better on day 8 and this difference was mainly driven by consolidated novel words. Taken together, these results suggest that the reverse effect of consolidation found on day 2 might be explained by recency since participants were tested on the unconsolidated novel words immediately after training. Furthermore, overall improved performance on day 8 driven primarily by consolidated newly learned words implies that testing had a bigger effect when applied after a night's sleep than immediately after training.

Resumen

El objetivo de este estudio fue investigar el rol que cumple el sueño en la consolidación de palabras nuevas recientemente aprendidas en inglés como lengua extranjera así como el efecto de la frecuencia de exposición a estas en relación a su adquisición. Los datos para este estudio fueron obtenidos de 20 participantes adultos estudiantes de inglés como lengua extranjera. A ellos se les presentaron 20 palabras nuevas en inglés, las cuales fueron divididas en dos sets de 10 palabras cada uno. La mitad de los participantes fueron expuestos a las palabras en solo una sesión de aprendizaje, mientras que la otra mitad en dos sesiones. Los participantes aprendieron el primer set de palabras y tuvieron una noche completa de sueño antes de aprender el segundo set el día siguiente y tomar el test de categorización semántica el cual midió la cantidad de respuestas correctas y el tiempo de reacción. Se les pidió a los participantes que tomaran el mismo test 8 días después de haber sido expuestos inicialmente al estímulo. El experimento reveló que las palabras consolidadas a través del sueño no tuvieron un mejor desempeño en comparación con las palabras no consolidadas en términos de respuestas correctas en el primer test. Sin embargo, 8 días después de la exposición inicial, las palabras consolidadas con un periodo normal de sueño mantuvieron su porcentaje de respuestas correctas, mientras que las palabras aprendidas sin previa consolidación se emparejaron con los porcentajes de respuestas correctas obtenidas por medio del sueño. A su vez, a los 8 días las palabras fueron categorizadas significativamente más rápido que en el primer test; mostrando siempre que aquellos participantes que tuvieron una doble exposición al estímulo, tuvieron una tendencia a desarrollar el test con mayor exactitud que aquellos expuestos solo una vez con o sin consolidación a través del sueño. En definitiva, los resultados indican que el efecto de recencia incrementó las respuestas correctas temporalmente obtenidas de palabras no consolidadas y que el sueño tiene un efecto estable y duradero a través del tiempo.

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Chapter 1-The role of sleep in the consolidation of novel words in English as a foreign language

1.1 Introduction

Language is not a ready-to-use ability that human beings are born with; it is rather an in-development system that becomes fully functional as newborns grow up. According to Tamminen (2010) the process of word learning starts at early stages of life and it seems that children are bound to acquire words to communicate basic needs that would not be fulfilled by recurring to basic sounds that other mammals do. In order to learn new words all human beings have to be exposed to new linguistic items, but to a certain extent, the process of learning is seemingly faster in children than in adults. The process of picking up new words and consolidating them afterwards is affected by external and internal factors, such as the role of visual referents in order to reinforce the meaning of words especially during childhood (Gentner, 1982), or sleep contributing to word consolidation (McGaghie, Issenberg, Petrusa & Scalese, 2006).

During infancy there is a time-window for fast acquisition of words. Children start acquiring natural languages as young as eighteen months of age (Tamminen, 2010) which accounts for the rapid acquisition of new words and the progressive complexity of their syntactical constructions (Miller & Gildea, 1987). This fast acquisition of core elements of language makes infants able to communicate their thoughts, needs and emotions as they grow up. Toddlers are immersed in the process of learning hundreds of new words because most of these words are unknown to them, whereas adults are likely to come across unfamiliar words less frequently. This process of learning vocabulary in a fast mapping paradigm is superior in children in comparison to adults because the environment demands the acquisition of lexical items that permit communication and fast access to information. Common examples of this type of word learning can be found in storytelling and television watching, where after only a single exposure children may have sufficient knowledge to recognize a new word (Swingley, 2010). Likewise, children learn nouns at a faster rate than verbs, presumably because most nouns usually have an obvious visual referent (are concrete) and are named frequently

(Gentner, 1982). Nouns are particularly accessible to infants since they have different shapes and are conceptually more basic than the concepts referred by verbs or prepositions. The fact that children are privileged word learners, nonetheless, does not mean that adult word learning stops at a certain point; adults still integrate new lexical items during their entire life and that is why humans are able to recognize a larger number of words in comparison to the ones they can produce (Laufer, 1998). The number of lexical items that we are able to recognize and produce is apparently dynamic, because even though we eventually could forget the meaning of words, we are still endowed with the phonological, syntactic and morphological clues (such as prefixes, free stems and bound roots) that permit word recognition to thrive (Solomyak & Marantz, 2010). Word learning is constantly active and is reflected for instance on how easily we understand words morphologically close, that is to say word families, despite this, word learning is by no means a simple achievement, the acquisition of new words relies on a set of multidimensional underlying systems as well as acquisition factors, including semantic richness, time of exposure, syntactic and phonological clues, among others. Word acquisition is affected by biological factors, for instance synaptic pruning, age, language-related brain diseases (De Bot, 2006), but in spite of these factors, language acquisition never stops and surprisingly, thanks to the new neural networks that the learning of a second language triggers, bilingual elderly people maintain a cognitive reserve that offsets neural deficiency as we grow old (Gold, Kim, Johnson, Kryscio, & Smith, 2013).

The process of language learning demands the integration of novel words in our mental lexicon, such process requires a storage system where lexical items can remain codified in a standby mode until contextual hints triggers the use. Scientific evidence suggests that the human brain is basically endowed with four main kinds of memory systems: Long term and short term memory as well as procedural and declarative memory traces (Tulving, 1985; Schacter & Tulving, 1994). For the purpose of our study, our main concern will be declarative memory traces. The declarative memory supports conscious recollection of facts and events such as factual knowledge of word and the meaning they possess (Squire & Zola, 1996). On the contrary procedural memory traces are not conscious and are expressed through the performance of abilities.

Finally, a simplistic approach might tend to lead to the conclusion that human beings would consolidate words immediately after learning as Lindsay and Gaskell (2013) have suggested in their latest study; however, scientific literature has provided vast evidence supporting the view that words are better recalled following periods of sleep (Gais, Lucas & Born, 2006; Dumay & Gaskell, 2003, 2004, 2007, 2012).

For the purpose of the study, we focused our experiment on how human beings learn declarative knowledge in the form of novel words and transfer them from short term memory to long term memory through a normal period of sleep. Other studies have already researched the effects of sleep on word learning, (Plihal & Born, 1997; Gais & Born, 2006) and have found a boost in declarative as well as procedural memory tasks after a full night's sleep; however, this research goes a step further as we are interested in how foreign language learners consolidate novel words in a foreign language. Since to the best of our knowledge, research has not focused on how much second language learning benefits from sleep in terms of word consolidation.

1.2 Adult word learning in a native language (L1)

Language users' mental lexicon is constantly changing. Therefore, the ability to keep adding words to their first language is not only children's regular practice but also adults'. The latter can still add words to their mental lexicon at any time of their lifetime; yet they do it in a different way and, to some extent, at a slower pace than children do when building up their native language (Leach & Samuel, 2007). Evidence from language development supports the view that the acquisition of new words is highly influenced by factors such as speaker gaze, syntactic context, current lexical knowledge and, time of exposure (Dumay & Gaskell, 2003). In the case of adult language users, learning new words is a rather surprisingly frequent event. In fact, it has been estimated that people learn about a thousand word forms (a word and its close morphological relatives) per year, which means that they learn approximately three new word forms per day. This suggests that lexical change is more active than we might expect (Nation & Warning, 1997).

Since adults are often exposed to new word entries, lexical configuration is needed to learn new words. In that sense, factual knowledge associated with a word's sound, spelling, syntactic role and meaning is fundamental to configure it. Most language users are exposed to some of this information primarily and more of it over time until lexical configuration is fully developed (Leach & Samuel, 2007). Dumay and Gaskell (2004) suggest that the lexicalization of a speech sequence seems to be confirmed when it engages in lexical competition since it affects the activity within the mental lexicon. The researchers have also looked at semantic information and whether providing it together with novel words' form during exposure would end up in a deeper and faster emergence of lexical footprints and lexicalization. In an experiment, they asked 30 adult British English native speakers to learn novel words, which were assigned meanings based on conceptual categories. Each novel word then appeared in two sentences; in the first one, the word category was explicitly mentioned and in the second one the word was included in a more general semantic context. During the training session, participants were divided into 3 groups. A given group of 10 participants was exposed to 12 novel words in a phoneme monitoring task, the other group of 10 participants to 12 novel words in a semantic verification task and the remaining 10 were not exposed to any of these

two exposure conditions. All participants were tested the same day with a Lexical Decision (LD) lexicalization test along with a two-alternative forced choice recognition test that assessed explicit knowledge of the novel words, and a free association task. On day two, the same tests were performed before further exposure took place. The tests were performed once again on day 8. This time without further exposure. The results suggested that novel word exposure in a rich semantic context did not necessarily result in a faster and deeper lexicalization compared to a simple phonological form exposure since only on day two there was a delay recognition of existing words from the participants who learned on the basis of just sound form. By day 8, the two conditions of exposure did not differ in terms of their lexical footprint effects. Therefore, this might suggest that going from simple storage to lexicalization of a word does not rely only on contextual meaning but on rather more complex factors such as time in the form of consolidation. This concept will be discussed in further sections.

Given the evidence above, adult word learning in L1 is a multifactorial process that has not been the immediate first focus of research since it has been very much focused on L2 word learning. However, Ferreira (2011) suggests that word learning in the L2 shares similar complex processes to those experienced when learning words in the native language including words' component such as phonology, orthography, and semantics.

1.2.1 Second language word learning in adults

The way in which people learn a first and a second language, although sharing complex processes, is in several aspects different. While the former mainly implies an unconscious acquisition process based on the eminent need of communicating with people around, the latter requires and demands a conscious learning process. Krashen (1981) has stated that the acquisition of a second language by children and adults is produced when they have a complete knowledge of their first language. According to this, children have a natural ability to grasp and acquire a new language and make up their own hypotheses for understanding the

world, whereas adults use the already existing knowledge to understand the new pieces of information (Kuhn & Pease, 2006).

Adult second language learners are keenly aware of their "vocabulary plight" and see acquisition of vocabulary as their greatest challenge since in the case of a target language, that learner is hearing or reading, containing too many unknown words, then that language is not comprehensible and therefore cannot be considered as input. In other words, the concept of comprehensible input introduced by Green and Meara (1995) help learners figure out how a language works and realize that without vocabulary comprehensible input is neither comprehensible nor input. Therefore, the ability to understand and generate sentences implies a meaningful process in which there is at least some implicit awareness of the lexical and syntactic contribution of component words to the total meaning of sentences (Ausubel, 1964).

Under these circumstances, context is crucial for adult learners, and the integration of personal real life situations to academic content is the main application of contextual learning available for them. It is thought that learners make a better sense of what is learned if they understand and grasp how it can be used in a real-world context. However, the emphasis does not remain on learners constructing their own meaning, but on developing accurate representations of the meaning intended through text. According to Dirkx, Amey, and Haston (1999) the context of real life situations and problems support adults' learning, since the meaning of what individuals learn is linked to their life experiences and contexts, and it is not constructed by their teachers, but by themselves. Through this type of acquisition, adult learners make a new set of words that are more familiar for them, and they are able to integrate new vocabulary into their mental lexicon.

On the other hand, the Cognitive Theory of Multimedia learning presents the idea that people do not learn a new word as deeply in isolation as when it is presented with pictures that represent its meaning (Mayer, 2005). According to Scott, Jamieson-Noel, and Asselin (2003) when learning new words associated with known concepts, or at the moment of learning definitions, the creation of visual images is very useful. Adults, unlike children, do not need to

acquire thousands of new concepts, but merely the new verbal symbols representing these known concepts (Ausubel, 1964).

In the field of memory research, two phenomena seem particularly relevant when it comes to second language teaching and vocabulary learning. These are the use of supporting images and the testing effect. Carpenter and Olson (2011) argued that images are remembered better than verbal labels. Likewise, Nelson, Reed and McEvoy (1977) encourage the use of images to provide a greater degree of elaborative semantic processing, which helps to achieve a better retention compared to just presenting words, whereas Van den Brock and Kremer (2000) explained that learners use mental images while reading in order to illustrate different key elements presented in the text, such as events, facts, and settings to describe the relationship between the elements in a meaningful way. Additionally, the testing effect is highly related to spaced learning and seems to be beneficial in adult word learning since the effortful retrieval of newly learned items has shown significantly better performance in explicit tests of memory involving recalling or recognition (Karpicke & Roediger, 2008) demonstrating that it enhances memory considerably compared with regular revision.

Above all, it seems reasonable to assume that when it comes to adults learning new words in a foreign language, they see acquisition of vocabulary as one of their greatest challenges, which is produced when they have a complete knowledge of their first language. Unlike children, adults use their already existing knowledge to understand the new pieces of information, that is to say, they do not acquire thousands of new concepts but in most cases, merely the verbal symbols representing already known concepts.

1.2.2 Word lexicalization and brain development

When newly acquired words are successfully integrated into the mental lexicon, they are considered lexicalized words; this means that they acquire the same features of words previously learned (Ferreira, 2011; Bakker, Takashima, Van Hell, Janzen & McQueen, 2015).

Novel words integrated in long-term memory possess factual knowledge (knowledge of morphology, phonology and meaning in context), procedural knowledge (use of language as a system) and activate specific neural networks in the brain when word meaning recognition either written or spoken takes place (Mc Laughlin, Osterhout, & Kim, 2004). It is likely that word learning in a second language shows similar activation and transformation of neural networks as in the mother language; however, Dehaene et al, (1997) found that neural activation tends to show greater dispersion across brain cortex when processing spoken L2 resulting in a continuous delay in language production, differently to native speakers that acquired their language from childhood, it is also worth mentioning that other studies have reported overlapping activation between both mother and foreign language, but it might be due to the low resolution of fMRI scanners (Van Heuven & Dijkstra, 2010). It seems that the point where most studies agree is that low proficiency learners engage in the usage of extra brain resources when producing language.

In the case of L1, during the early stages of language acquisition and production, the ability of children to constantly process language is remarkable, first recognizing basic language-related system clues within the contour of phonemes (Werker & Curtin, 2005), then at a prosodic level and finally at suprasegmental levels of language. In addition, apart from word recognition, what may be more remarkable is the long-lasting capacity of storing words in memory for later recognition and semantic comprehension. The latter is actually boosted by maternal sensitivity and responsiveness (for instance point an object while naming it) to the signals of their children, which promotes cognitive linguistic advances when learning the first words of the mother tongue (Baumwell, Tamis-LeMonda & Bornstein, 1997).

As previously stated, word learning is a complex process assisted and mediated by biologically underlying systems that allow a time-window for fast acquisition at early stages of life. At first, these steps of language learning do not occur at a word level; rather, words are the top outcome of language systems in previous and ongoing development. Those systems include for instance, language processing lateralization and the maturation of phonological

recognition that endows toddlers with the ability to recognize single-phoneme traces and subsequently the capability of assigning them semantic meaning.

Scientific literature regarding the effect of age and biological factors in language acquisition abound. Stager & Werker (1997) discovered that children at the age of 4-6 months are better at discriminating phonetic changes than their counterparts aged 10-14 months, suggesting that when learning words rather than syllables at older stages, children tend to ignore phonemic variations that do not change the message semantically, whereas, newborns are sensitive to a wider range of sound variation, probably for they have not structured the language at a word level.

Another study conducted by Mills, Coffey-Corina and Neville (1993) discovered that as the language learner leaves childhood, the systems underlying language learning apparently undergo a process of specialization increasing language efficiency; namely at early stages of language learning our brain processes language input rather bilaterally, but as increasing language lateralization takes place in the parietal and temporal regions of the left hemisphere, our language abilities improve.

Research conducted by Mills et al. (1997) shed light on revealing the hidden biological changes as a result of neural specialization; the researchers measured the EEG electrical patterns in children's brains when being presented semantically meaningful words as opposed to novel words. The researchers found that children experienced longer responses in the brain when recognizing semantically meaningful words in contrast to lower neuronal activity when they come across novel words. Furthermore the results also suggest an increased capacity of word recognition as the brain becomes more specialized in language processing, forcing it to start a migration towards left lateralization. This process of continuous language lateral specialization is correlated with left hemisphere processing of language that, as previously explained, is rather bilateral at early stages of development.

Knowing that our brain is able to lexicalize word-like items producing neural transformations, there is no definite explanation on how the human brain labels novel items with semantic meaning, nevertheless, Goodman, McDonough, and Brown (1998) conducted a study that provides a tentative explanation on how contextual clues in the realm of spoken

sentences might provide the basic scaffold for discovering the meaning of words in connection to items within sentential boundaries. Their study revealed that 2-year old children are able to discover the meaning of novel words when presented in spoken sentences that were semantically meaningful and that its syntactic links facilitated relationships between words within the boundaries of the sentence. Essentially, they construct the meaning based on semantic context and syntactic clues.

The human brain is the most fundamental piece of biological machinery in charge of language learning, processing and production. From a holistic approach we might tend to think of language as a whole, a system that is somehow stored and modified in the brain without full comprehensive explanation; however, clinic cases of brain damage account for selective language impairments linked to anatomically specific brain damage (Stephens, Silbert & Hasson, 2010). An exploratory case would be the Broca's aphasia that tampers with language comprehension and production. As far as research has disclosed, language is stored and processed in anatomically different brain regions (Price, 2000) and even more complex, the memory systems that underlie the storage of language are divided into long term memory and short term memory, both divided into many other branches (Schacter & Tulving, 1994) such as working memory, semantic memory, episodic memory, etc.

1.3 Memory systems and language storage

In the 19th century, the profound skull injury documented in Phineas Gage's medical case, suggested the existence of functionally specific brain regions performing different but related tasks (Damasio, Grabowski, Frank, Galaburda, & Damasio 1994). Later on, this case led scientists, aided by neuroimaging technology, to identify at least four different types of memory: Short term memory, long term memory, procedural memory and declarative memory. The theory of multiple memory systems for a long time was essentially based on behavioral experiments but naturally this approach lacked biological support reinforcing the findings; nonetheless, new research in the field of neuroscience has reinforced the theories previously stated. Packard, Hirsh, and White (1989) developed a reliable research based on

experimental tests that have supported the idea of the existence of anatomically distinct memory systems, which will be addressed in the following sections.

1.3.1 Short-term memory

Short-term memory is one of the human brain storage and retrieval information systems that research has identified across behavioral and anatomical studies (Cave & Squire, 1992); however, there is no consensus whether short-term memory is a single unitary system or it is divided into subsystems supporting different memory traces and abilities. Baddeley's (1992) findings have provided insight on the existence of one main working memory and two slave systems supporting intrinsic capacities such as language comprehension, learning and reasoning. Baddeley's (1992) model of short-term memory considers that one of the working memory slave systems (phonological loop) tackles specifically auditory input for later analysis and retrieval, likewise, Gathercole (1999) reviewing the short-term memory systems, concludes that there is a phonological short-term memory, linked specifically to the learning of new words' phonological structures. Therefore, the fact that language acquisition can take place as an auditory representation might be a critical factor especially in foreign language learning. This hypothesis was reinforced by the study of Gathercole, Hitch, and Martin (1997) who discovered that word learning in children is directly involved with phonological short term memory capacity, so that this kind of memory might be a reliable predictor of vocabulary acquisition.

In terms of anatomically specific functions, the brain structure called hippocampus has been heavily involved as a part of the biological machinery that allows declarative memories to be successfully transferred to long term memory or stored for a short span of time until a natural decay of these memory traces happen. The distinction between short-term memory as opposed to long-term memory has been developed within experimental psychology by Wickelgren (1975) and emphasized by James (1980). New facts or events, commonly called declarative memory traces, such as novel words presented with or without context, are stored in this called short-term memory (among others), but necessarily these memory traces need a

period of consolidation in which short-term memory is encoded into long-term memory. The capacity of long-term consolidation is heavily or completely impaired in those patients diagnosed with amnesia related to hippocampal damage; nonetheless, behavioral experiments carried out by Cave and Squire (1992) reported that short-term memory remains seemingly normal and functional in those subjects diagnosed with amnesia in comparison to healthy subjects. Experiments carried out to assess the functioning of short-term memory mainly consisted of verbal and non-verbal activities in which the subjects had to retain and retrieve accurate information already learned. For instance the digit span test in which verbal information about a number sequence was presented, reported no significant differences within the control group and amnesic group related to confirmed damage in the hippocampus, only amnesic patients related to frontal lobe atrophy showed a significant impairment in verbal tasks. The results of the study performed by Cave (1992) reported that short-memory impairments are significant in those amnesic patients diagnosed with Korsakoff's syndrome. The results supported the view that short-term (immediate) memory is functionally independent from long-term memory, and also that short-term memory is at certain point independent from the hippocampus.

The short term memory (STM) is not a single entity (Baddeley, 1981), but a collection of separate capacities intrinsic to information-processing systems (Cave, 1992), for instance working memory, a kind of short term memory, is able to support processing and learning in a vast variety of contexts (Gathercole, 1999), and it has also been linked to supporting visual memory (Klauer & Zhao, 2004).

Considering that our study is related to word learning, word recognition, and word consolidation, it is interesting the fact that Gathercole, Hitch and Martin (1997) discovered that word learning is directly involved with phonological short-term memory skills. The study consisted in presenting children aged five, a battery of four experimental tests. These tests were based on phonological and non-phonological learning activities. The first test consisted of the classic digit-span verbal test in which the subjects had to memorize a series of numbers accurately, those series were communicated verbally and therefore stored as an auditory

image, the second task consisted of memorizing word-word and word-non-word paired lists. The results of the digit span measure is closely related to those subjects who reported a high amount of vocabulary availability, the three vocabulary tests correlated strongly with the results obtained in the digit-span tests by the same participants. The children that scored higher in word-non-word recall also showed superior capacity for learning new words; furthermore, there were no significant differences in comparing the results of the digit-span task and the word-nonword paired list recall related to vocabulary learning tests, which means that both tests are very consistent in measuring phonological short-term memory performance as a predictor of vocabulary acquisition.

A reverse correlation between phonological memory performance tests and already available vocabulary was carried out; the results reported that those participants who possess a high lexical availability are also better at remembering non-words in comparison to subjects with a poor availability of vocabulary. This suggests that lexical knowledge may support both phonological and non-phonological aspects of verbal learning. The correlations between performances in verbal tasks led to conclude that children's ability to learn new phonological structure of novel words is supported by both: their capacity to maintain verbal material as an auditory image in short-term memory, and their vocabulary knowledge, more specifically the knowledge of phonological system patterns of the language they are learning or immersed in.

1.3.2 Long-term memory

The human brain, according to Kutas and Federmeier (2000), stores vast amounts of diverse types of information, such as information about people living in the neighborhood, everyday objects and details regarding what they look, sound, feel, smell and taste like, even more, recently Zucker and Ranganath (2015) discovered that the hippocampus stores the neural network representation of places where we have been in. As the brain deals with different memories traces, the brain stores different kinds of information,, for instance the implicit memory or procedural memory that has to do with the performance in tasks and the

acquisition of abilities such as learning the steps to drive a car or produce speech in a foreign language. In the case of our study, our main concern is focused on the consolidation of declarative memory traces in the long-term memory.

According to Gais and Born (2004) declarative memory traces are not stored directly into long term memory, for that to happen, the hippocampus serves as buffer-like memory in which memory traces coming from the entorhinal cortex (BuzsÁk, 1998) undergo a process of early consolidation while available to be recalled instantly. Afterwards during sleep, early consolidated memory traces are apparently transferred from the hippocampus to long-term memory where they become long-lasting and independent from the hippocampus (McClelland, McNaughton & O'Reilly, 1995). Other studies reinforced the finding that long-term memory interplays with the hippocampus, but also that sleep plays a key role in the interplay between the hippocampus and neocortex for the consolidation in long-term memory to thrive (Walker & Stickgold, 2004).

As it has been explained, the memory trace of our concern, the declarative memory, once consolidated is stored into long-term memory. That hypothesis has been reinforced by actual insight coming from changing electrical activity in language related brain structures, as well as the N400 neural response complex when words are semantically meaningful (Kutas & Federmeier, 2011).

1.3.3 Declarative Memory

Declarative memory is defined by Eichenbaum (2011) as available to conscious recollection and subject to verbal or other explicit means of expression. In other words, the declarative memory stands for the storage and retrieval of episodic and semantic memory traces such as events and lexical items respectively. The process of storing words in our brain is mediated by an important naturally recurring state, characterized by reduced or absence of consciousness: such process is called sleep. The role of sleep in the consolidation of

declarative memory is crucial for triggering biological changes that lead to long-lasting storage of semantic and episodic knowledge.

According to Diekelmann and Born (2010), the sleep process is divided into two stages; the first stage is called NREM sleep, mostly associated with low brain activity, low hormonal production and a decreased wave spindle of bioelectrical activity, called regularly SWS sleep. This stage is associated with the consolidation of semantic memory such as words or events. On the other hand, the second sleep stage is called REM sleep; this stage, characterized by rapid eye movement, presents an increased brain activity in both electrical activity and biochemical interaction of neurotransmitters and hormones. This REM activity is related to procedural memory consolidation such as how to swim, solving problems, learning a new language, etc.

The declarative memory traces, containing factual information, are known to remain in an early consolidation memory buffer called hippocampus, and then overnight transferred to the neocortex (Lisman & Grace, 2005). Once the declarative memory traces have been consolidated -in other words codified into long term memory they can be recalled faster even after several days after initial acquisition. In the case of word-like items, when presented in speech or in a text, the brain looks for them automatically in the mental lexicon, which triggers the N400 neural response. In brief, it means that word-like items not only can be stored but also recalled back activating all the knowledge we have about that lexical item, for instance word-meaning in the case of the N400 neural response (Kutas & Federmeier, 2011). Finally it must be observed that the effects of declarative memory consolidation such as faster words recall and N400 activation only appear after a full night of sleep.

1.4 Word consolidation and sleep

As previously discussed, sleep seems to be a powerful aid in memory consolidation since it allows the process of restructuring representations in memory to promote the extraction of explicit knowledge from implicitly encoded information, such process occurs during slow-wave sleep in which newly encoded representations stored temporarily in

hippocampal networks are reactivated to be transformed and redistributed to neocortical networks for long-term storage (Wilhelm et al, 2013) and as any kind of knowledge, vocabulary acquisition also seems affected by the process of consolidation in a rather critical way. Dumay and Gaskell (2012) have contributed with the hypothesis that one night's sleep, or even a nap, induces dramatic changes in the way novel words are represented in the brain and contributes to the dynamics of language processing.

The effects of consolidation have been demonstrated mainly by data obtained from subjects' performance regarding the engagement of newly- acquired novel words in lexical competition either at a phonological or semantic level as the ability to engage in lexical competition indicates a key marker of lexical representations in a visual domain as well as in a spoken one. Studies that have provided such evidence will be addressed in the following paragraphs.

Several studies investigating the relationship between sleep and the consolidation of words have been carried out. Early research conducted by Plihaland Born (1997) measured the effects of early and late nocturnal sleep on declarative memory, specifically word learning through a recall task. The method to conduct this experiment consisted of two groups of people that had to learn a set of paired words, then after a specific span of time, one group had to sleep and the other stayed awake, both for three hours. The test applied drew as a result that the early sleep group outperformed the group that stayed awake. Such results led to consider the role of SWS sleep waves in the first period of sleep by judging the hormone cortisol level in both groups. Likewise, Dummay and Gaskell (2003) reported that the integration of a newly learned word forms with existing knowledge in the mental lexicon requires an incubation-like period crucially associated with sleep. The observation of engagement in lexical competition and lexicalization taking place only within 24hr after exposure of novel words ultimately indicates change in lexical activity after the incubation-like period just mentioned.

This supports the idea that in order to avoid new learned information disrupting preexisting knowledge, the human brain relies on a dual-learning system in which new information is initially separated from existing knowledge so that it can be interleaved off-line over a longer period of time transferring it into long-term neocortical memory during sleep

which indicates that sleep has a fundamental role in memory consolidation in terms of the recovery of procedural details related to learning of speech acquired but sometimes lost over the preceding day and also promoting abstraction of syntactic dependencies (Gomez, Bootzin, & Nadel, 2006).

Research conducted by Campbell and Feingberg (2009) claims that one of the reasons why children learn vocabulary at a much greater rate is because they sleep longer and more deeply than adults indicating that sleep has a key role. The study carried out by these researchers had children between the ages of 7 to 12 who showed sleep associated consolidation effects in declarative but not procedural memory and also showed that the relationship between sleep and word learning in children is remarkably similar to the patterns for adults. Accordingly, it reported improvements in children's ability to recall and recognize novel nonwords 24 hours after training (Brown, Weighall, Henderson & Gaskell, 2012). Importantly, they found no such improvements 3–4 hours after training, suggesting that improvements at the 24-hour retest were not due to practice effects or repeated exposure. Such findings are similar to the ones obtained by Dummay and Gaskell (2003) in adults. In another attempt to look closer to the relationship between nocturnal sleep and consolidation of spoken words regarding engaging in lexical competition; the researchers, gathered A.M and P.M groups formed by 64 native English speakers who learned nonsense words and were tested on lexical activity and explicit memory immediately after exposure, 12 and 24 hours later. The results obtained from this study supported the researchers' hypothesis since engagement in lexical competition was not observed shortly after exposure, nor after a day awake, but was consistently found after a night's sleep. Such results suggest once again that lexicalization is associated with nocturnal sleep and not simple the passing of time (Dummay & Gaskell, 2007).

Given the above evidence, it appears that the idea of sleep playing a key role in the consolidation of words is not just a vague idea that has been around for a considerable amount of time, research has looked deeply into this topic and has found consistent evidence, yet most research has focused on the consolidation of newly learned word in the first language, more specifically, on the effect of sleep when English native speakers learn English novel words. However, to the best of our knowledge Gais, Lucas and Born (2006), in an attempt to

contribute to the belief that declarative memory benefits from sleep, are the only resarches who have used words in a foreign language as stimuli yet in a rather different way than in our study. The researchers used English words paired to German words in the form of vocabulary lists containing nouns and verbs that in some cases were cognates on sheets of paper and presented them to high school students who were native English speakers with no prior knowledge of German. Although in such experiment foreign words were used, the main difference between this and our study is that in ours the main focus is on how bilinguals or second language learners acquire new words in a language different from their native one inside a second language setting where instructions, learning sessions and testing sessions were conducted in the target foreign language.

Even though the focus of research on Gais et al. (2006) was not foreign language learning, results indicate that sleep following learning has beneficial effects on declarative memory consolidation in humans stressing the fact that data showed that sleep is more effective when it follows within a few hours after learning without longer periods of intervening wakefulness. Therefore, it would be interesting to see whether sleep has the same or similar effect when bilingual speakers learn novel words in the second language that they are familiar with taking into consideration that learning words in a second language is a conscious complex process and rather different from learning words in a first language.

1.5 The study

In order to determine the role of sleep in the consolidation of novel words in English as a foreign language, 20 EFL speakers from Universidad Católica de la Santísima Concepción, whose native language was Chilean Spanish, were invited to take part in an experiment. They were asked to learn 2 sets of novel words in English containing living and non-living nouns over the course of two days. On day 1, participants were asked to learn one set and have a full night's sleep. On day 2, they learned 10 more words and were tested immediately after exposure using a semantic categorization task. Eight days after initial exposure, participants were asked to take the test again without further instruction.

Chapter 2 – Problem statement and research proposal

2.1 Justification

The acquisition of a language entails learning several aspects of its system such as pronunciation, pragmatics, syntax, etc. However, one of the most fundamental features of learning a new language is the acquisition of new words. Building up a richer mental lexicon ultimately means better understanding and comprehension along with better communication skills which are less dependent on non-verbal resources. Much emphasis has been given to how second language users learn new words in terms of teaching methodology, strategies, and approaches used. Nevertheless, not much attention has been drawn to biological aspects, which are the building blocks of the cognitive processes we all share. One particularly important aspect is neuroplasticity and the mechanisms responsible for it during sleep. On that account, we attempt to contribute and expand the current scientific knowledge regarding this not-deeply-explored area by focusing our research on the role of sleep in the learning of vocabulary in a foreign language. To the best of our knowledge, sleep studies of word learning have primarily focused on L1 (Campbell & Feingberg, 2009; Dummay & Gaskell, 2007) showing that during sleep learners consolidate newly learned words in such a way that lexicalization cannot be attributed to the simple passing of time. Therefore, we would like to investigate second or foreign language in order to determine if a similar phenomenon occurs regarding the learning of new words in L2.

2.2 Research Questions

- Does sleep affect the learning of novel words in English as a foreign language?
- Does participants' performance improve after a full night's sleep?
- Do learners with double training outperform learners with single training in the learning of novel words in English as a foreign language?

2.3 Objectives

2.3.1 General objective

To investigate the role of sleep in the learning of novel words in English as a foreign language.

2.3.2 Specific objectives

- To identify the role of sleep in the learning of English novel words
- To determine the influence of training (frequency of exposure) on the learning of novel words in English as a foreign language
- To assess the role of word consolidation in the learning of novel words in English as a foreign language

2.4 Variables

2.4.1 Independent Variables

Sleep

For the purpose of this study, sleep will be understood as nocturnal rest, which consists of a period of six to eight hours of uninterrupted sleep per night

Frequency of exposure

Frequency of exposure will be understood as the number of times that a participant is exposed to novel words in training sessions before performing tests

Day

In the particular case of this study, days will be defined as intervals in which testing sessions take place

2.4.2 Dependent Variables

Reaction Time

Reaction Time will be operationally defined as the time in milliseconds that participants take to respond to each task included in testing sessions

Accuracy

Accuracy is the percentage of correct responses participants provide during testing sessions

2.5 Hypotheses

- Sleep affects the learning of novel words in English as a foreign language
- Learners with double training outperform learners with single training in the learning of novel words in English as a foreign language
- Participants' performance improve after a full night's sleep

Chapter 3 – Experiment

3.1 Introduction

This experiment attempts to investigate the role of sleep and the influence of training (time of exposure) in the consolidation of novel words in English as a foreign language, and the potential interaction between these variables. Many studies have addressed how word learning benefits from periods of offline consolidation. In line with the previous experiments conducted by Dumay and Gaskell (2003, 2004, 2007, 2012), we predict that sleep affects the learning of novel words not only in a native language but also in a foreign language. However, we predict that sleep is not the only factor that affects word learning, we expect that learners with double training eventually will outperform learners with single training in the learning of novel words in English as a foreign language and finally that there is an interaction between sleep, training and word consolidation.

The current study consists of the presentation of a set of twenty novel words in English containing 10 living and 10 non-living nouns (see Appendix 3.1), such words were divided and distributed into two sets of 10 words containing 5 living and 5 non-living words each (see Appendix 3.2). These sets of words were presented in two training sessions and participants were tested in a semantic categorization task.

3.2 Main Experiment

3.2.1 Method

Participants

A total of 20 EFL learners (mean age 22.6, SD 1.8) English undergraduate students at Universidad Católica de la Santísima Concepción, whose native language was Chilean Spanish and had been enrolled in English language classes for at least 3 years, volunteered to take part in the study. Eight of the participants were male and 12 of them were female. It is

important to note that none of the subjects had a record of any language disorder or learning disability and had normal or corrected-to-normal vision. Participants gave informed consent and received payment for participation.

Materials and design

Twenty novel words in English were created and paired with real but obscure concepts (For example, *sernal* was paired with *The Phaistos Disc* which is a stamped disk of fired clay from the Minoan palace of Phaistos on the Greek island of Crete). As they all were concrete nouns, they were trained in association of pictures corresponding to rare animals or rare objects in order to have 10 living words and 10 non-living words. The novel words used as stimuli in the learning sessions were also accompanied by 5 sentences which identified specific features per concept (range 6-23) (See Appendix 3.3) and a sound file with the corresponding British English pronunciation. The novel words used in this experiment were part of the stimuli used in Ferreira (2011).

The stimuli were distributed into learning sessions using the E- Prime software in order to create two sets of words, which contained 5 living and 5 non-living novel words. These training sessions apart from containing all the information mentioned above, showed the stimuli in a randomized order and included tasks in which participants had to re-type the newly learned words and write the suitable non word when only features were presented in order to help them learn and retrieve the novel words later on (See Appendix 3.4 and 3.5).

In order to test participants, a semantic categorization task was used. It consisted of the display of the stimuli previously presented in the learning sessions. Subjects were required to categorize them into living and nonliving. Using E- prime 2.0 (Psychology Software, 2012) the display started with the presentation of 4 familiar word practice trials that participants categorized first in order to get to know the task before moving on to the actual test. It began with a fixation cross showed on screen for 1 second followed by a 500 millisecond- lasting black screen and the display of trained word for 5 seconds, during this period of time subjects

were expected to categorize the novel word by pressing 1 for living or 2 for non-living on the computer's keyboard as fast and accurately as they could since responses regarding reaction time and accuracy were recorded for analysis. (Appendix 3.6)

Procedure

The experiment was conducted over the course of three days, two consecutive days along with an extra session 8 days after initial exposure to the stimuli. The first stage of the experiment was the learning session in which subjects were randomly allocated into single and double training. Hence, half of the group went through the learning session once and the other half twice. E- Prime 2.0 (Psychology Software, 2012) was used to present the stimuli across both sessions (sets A and B).

During the first learning session (Day 1), participants were exposed to a set of 10 novel words containing 5 living and 5 non-living items. The first 10 participants were presented set A on day 1 and the second 10 participants were presented set B on that day in order to counterbalance the participants. The first learning session lasted approximately 10 minutes. Participants who were assigned double training were given a five-minute break and were asked to undergo the learning session again. All participants were also advised to sleep between 6 to 8 hours, and not to consume alcohol or prescription drugs that could interfere with their sleeping patterns.

The following day (Day 2) participants went through the second and last learning session in which subjects were exposed to their corresponding set (set B for participants who learnt set A the previous day and set A for the ones who learnt set B first), as done in the first learning session, subjects who were assigned double training on day 1 also were assigned double training on day 2 and were given a five-minute break after repeating the learning session. Participants were tested using the semantic categorization task immediately after the training on the second set of words on day 2, so they had a full night's sleep after learning the first set and no sleep after learning the second set.

Eight days after initial exposure to the stimuli, participants were asked to come back in order to repeat the testing session using the semantic categorization task. This time the test was performed without further exposure to the stimuli.

Chapter 4 - Results

After the last testing session on day 8, the data collected from the 20 participants that took part in the experiment was analyzed conducting two-tailed t-tests for paired samples as well as for independent samples with 95% confidence. The results obtained using the statistical software SPSS were divided into accuracy and reaction time (RT). Accuracy stands for the percentage of words that subjects were able to categorize correctly into living and non-living after a given span of time while RT stands for the time in milliseconds (ms) that it took participants to decide whether a lexical item was a living or nonliving thing.

Analysis 1 compared the means of the words that underwent a period of consolidation mediated by sleep and the ones that were learned on the same day of testing, so that not consolidated overnight.

4.1 Word consolidation (day 2)

Table 1

Mean accuracy on day 2

	Sleep condition	Non-sleep condition
Mean %	70	76
SD	19.4	18.7
N participants	20	20

A paired sample t-test reported non-significant effect of sleep in word consolidation $t(19) = -1.143, p = .267$.

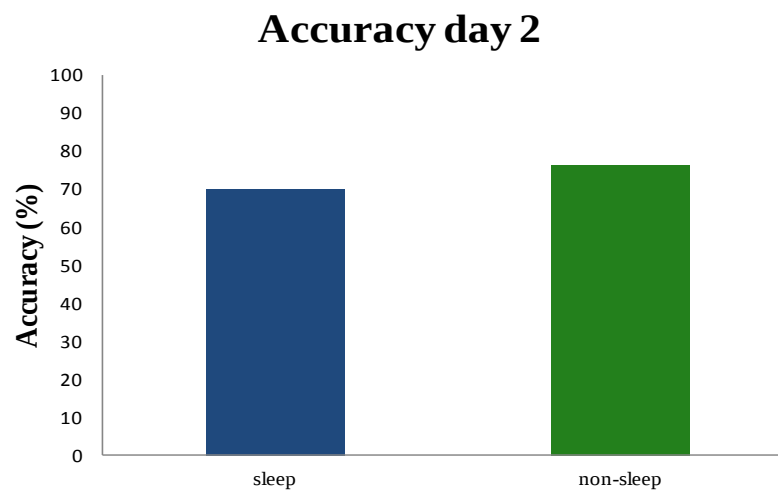


Figure 1 Accuracy on day 2, corresponding to the sleep and non-sleep condition

When analyzing reaction time in the living and non-living forced choice test (see Table 2), a significant difference between words consolidated during sleep and non-sleep conditions was found $t(19)=2.68, p=.05$.

Table 2

Mean reaction time measures (RT) on day 2

	Sleep condition	Non-sleep condition
Mean (RT) in milliseconds	1402	1286
Standard deviation	307	245
N participants	20	20

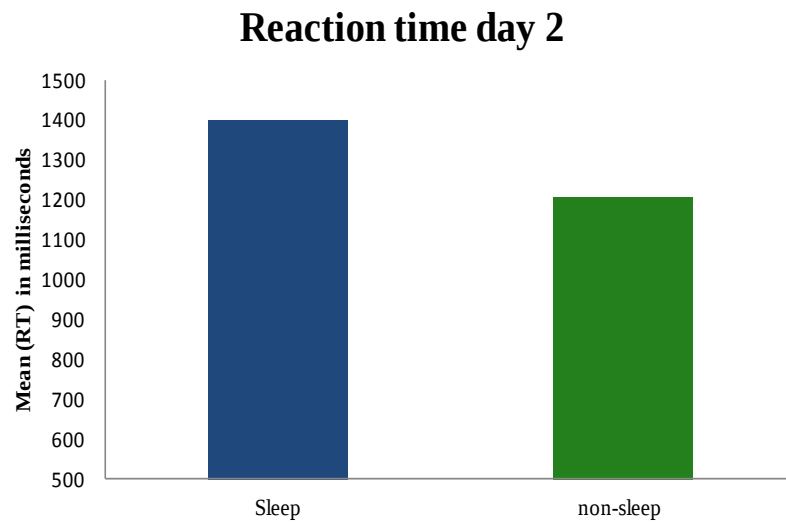


Figure 2 Reaction time on day 2, corresponding to the sleep and non-sleep condition

4.2 Word consolidation results on day 8

A second testing session was carried out 8 days after the first learning session. The calculations performed by a paired sample t-test on the accuracy measures, brought about non-significant distinctions in the consolidation of words learned initially on the first day (early consolidation) compared to the second day (late consolidation) $t(19)=-0.433$, $p=.670$.

Table 3

Mean accuracy on day 8

	Sleep condition	Non-sleep condition
Mean %	70.5	72.5
Standard deviation	20.1	15.5
Nparticipants	20	20

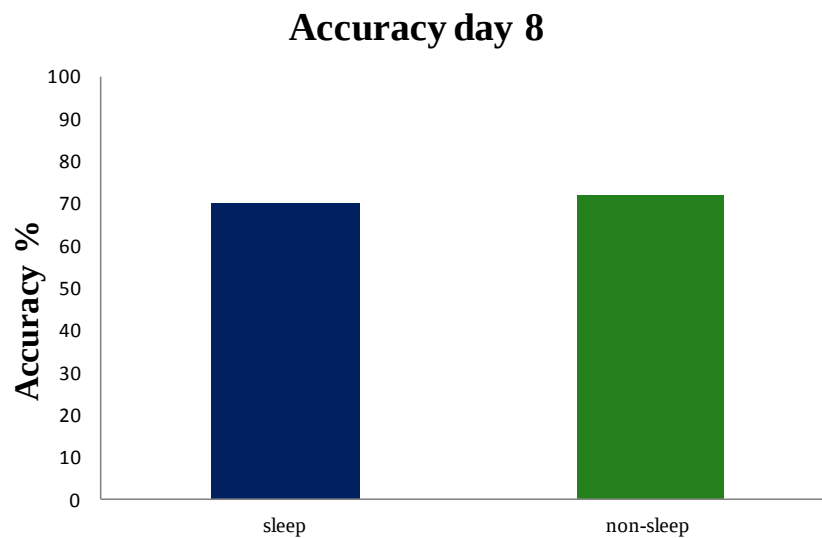


Figure 3 Accuracy on day 8, corresponding to the sleep and non-sleep condition

The results drawn by a paired sample t-test on reaction time measures provided non-significant distinctions between the words learned on the first day (early consolidation) and on the second day (late consolidation) $t(19)=0.840$, $p=.412$.

Table 4

Reaction Time measures Day 8

	Sleep	Non-sleep
Mean (RT) in milliseconds	1170	1125
Standard deviation	335	268
N participants	20	20

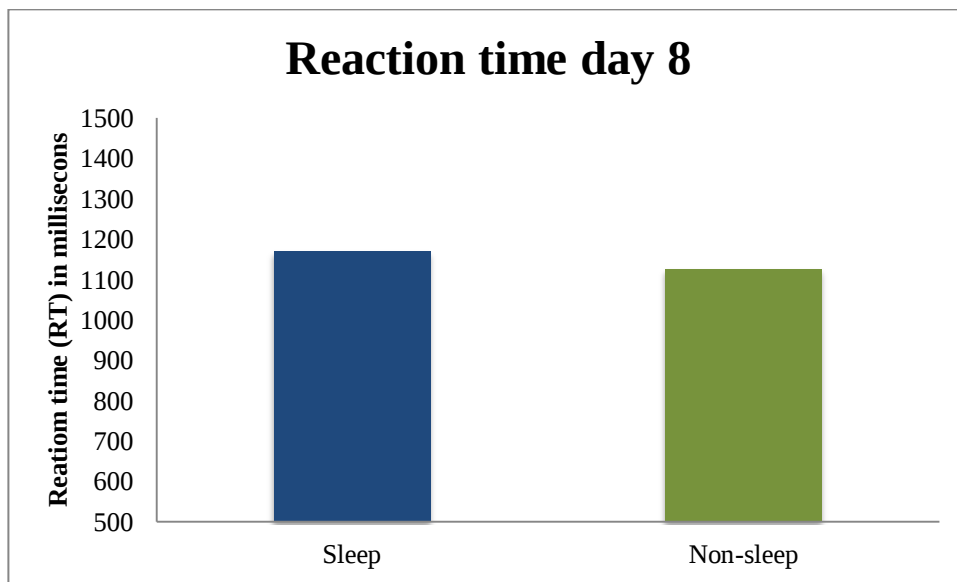


Figure 4 Reaction time on day 8 corresponding to the sleep and non-sleep condition

4.3 Word consolidation results for day 2 versus day 8

Accuracy

When comparing the measures of words that underwent early consolidation before testing and a post-test recalling the same set of words 8 days after, bring about the following results.

Table 5

Accuracy of words learned on day 1

	Testing measures on day 2	Testing measures on day 8
Mean %	70.0	70.5
Standard deviation	19.4	20.1
N participants	20	20

The first testing session reveals a consolidation mean of 70% of words correctly labeled as living and non-living which compared to the mean drawn 8 days after 70.5%, does not bring any significant difference between both time-distant measures $t(19)=-.027$, $p=0.9$.

In the case of words that had been learnt on the same of testing (day 2, late consolidation) when recalled in a new testing session on day 8, both measures do not provide statistically significant results $t(19)=1.0$, $p=0.330$.

Table 6

Accuracy measures of words learned on day 2 (Late consolidation)

	Testing measures on day 2	Testing measures on day 8
Mean %	76	72.5
Standard deviation	18.7	15.5
Nparticipants	20	20

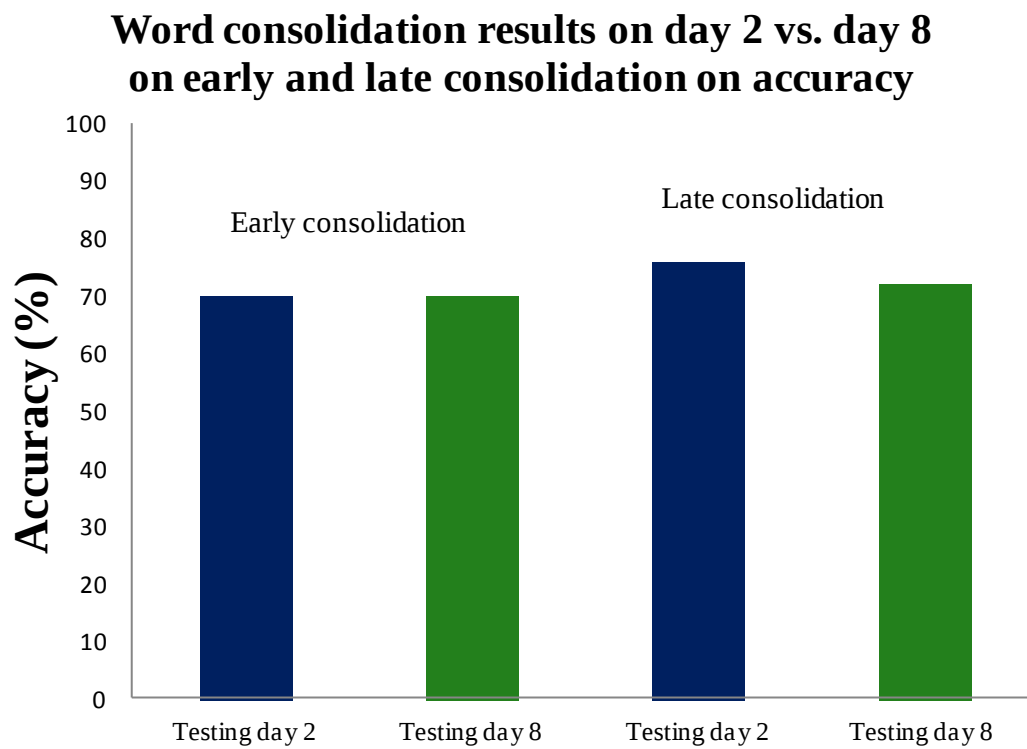


Figure 5 Word consolidation results on day 2 vs. day 8 on early and late consolidation (accuracy)

4.4 Word consolidation results on day 2 versus day 8

Reaction time

The first testing session applied to the early consolidation word set on day 2 brought back a mean of 1402 milliseconds. The same test applied on day 8 brought back a mean of 1170 milliseconds, results that once processed using a paired-sample t-test showed a significant difference between the conditions, $t(19)=3.308$, $p=0.04$.

Table 7

Reaction time measures for early consolidation word set

	Testing measures on day 2 (RT)	Testing measures on day 8 (RT)
Mean (RT) in milliseconds	1402	1170
Standard deviation	307	335
N participants	20	20

Comparing both means of late consolidation words, namely day 2 and day 8, the analysis brought back a statistically-significant result when comparing both measures $t(19)=3.504$, $p=0.02$.

Table 8

Reaction time measures for late consolidation word set

	Testing measures on day 2 (RT)	Testing measures on day 8 (RT)
Mean (RT) in milliseconds	1286	1125
Standard deviation	245	268
N participants	20	20

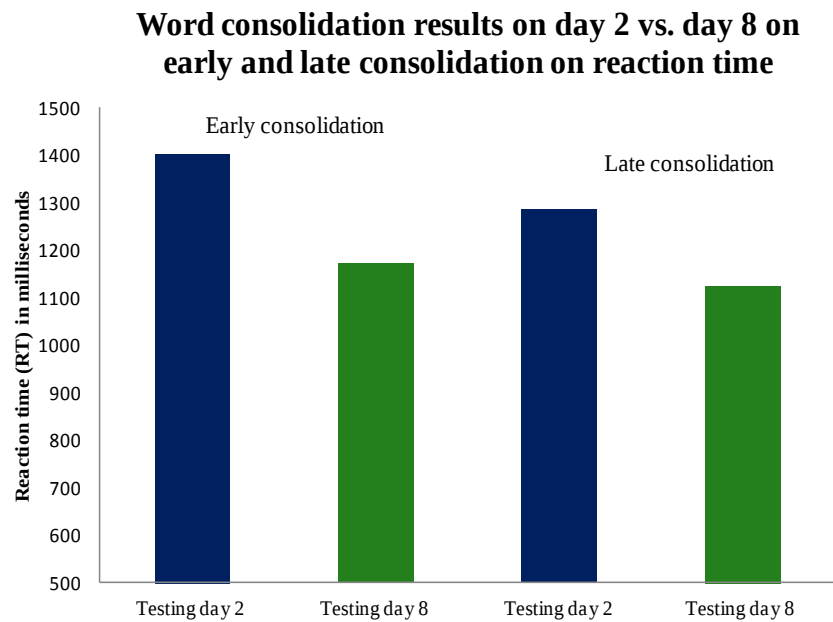


Figure 6 Word consolidation results on day 2 vs. day 8 on early and late consolidation (reaction time)

4.5 Word consolidation results in two different training groups

Accuracy on day 2

Table 9

Early-consolidation word-set results on day 2

Group	N	Mean %	SD
Training once	10	68	21
Training twice	10	72	18

Regarding the early-consolidation word set, the first testing session on day two reports for the single-training session group a mean of 68%, while for the double-training session group the mean is 72%. Although the results are noticeable different in favor of double-training session group, the results are not statistically significant $t(18)=-0.450$, $p=0.658$

Table 10

Late-consolidation word set results on day 2

Group	N	Mean %	SD
Training once	10	71	21,3
Training twice	10	81	15,2

In the case of late consolidation results (words learned on the same day of testing), the measures for the single training session had a mean of 71%, while the double-training session group obtained a mean of 81%, results that when analyzed, do not bring back any significant result either $t(18)=-1.2$, $p=0.243$. Despite the absence of significant results from a statistical point of view, in every single test the double-training session group surpassed the results of the single-training group.

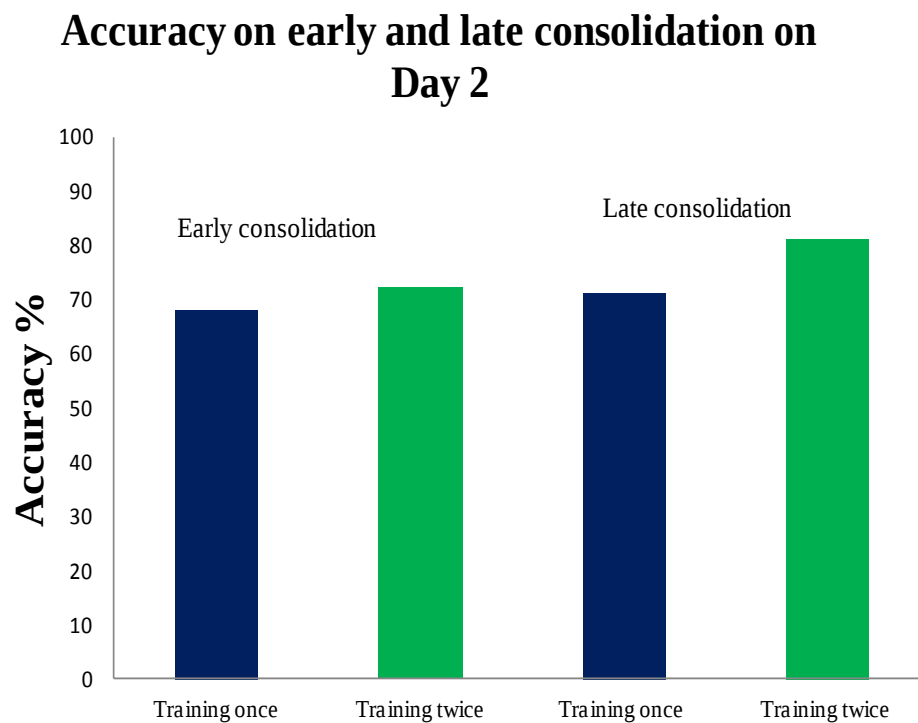


Figure 7 Accuracy on early and late consolidation results on day 2

Accuracy on day 8

The last testing session on day 8 for both groups, single and double-training sessions, brings about the following results: In the case of early-consolidation word set, the single-training session group had a mean of 62%, while the double-training session group reaches a mean of 79%. The means in this case differ significantly when comparing both measures $t(18)=-2.04$, $p=0.05$.

Table 11

Early consolidation word-set results on day 8

Group	N	Mean %	SD
Training Once	10	62	20
Training twice	10	79	15

Congruently with the previous results, in the late consolidation word set, the single-training group mean is 69%, while for the double-training session the mean is 76%. Comparing both means from single and double-training session brings back a non-significant result $t(18)=-1.0$, $p=0.326$.

Table 12

Late consolidation word-set results on day 8

Group	N	Mean	SD
Training Once	10	69	18
Training twice	10	76	11

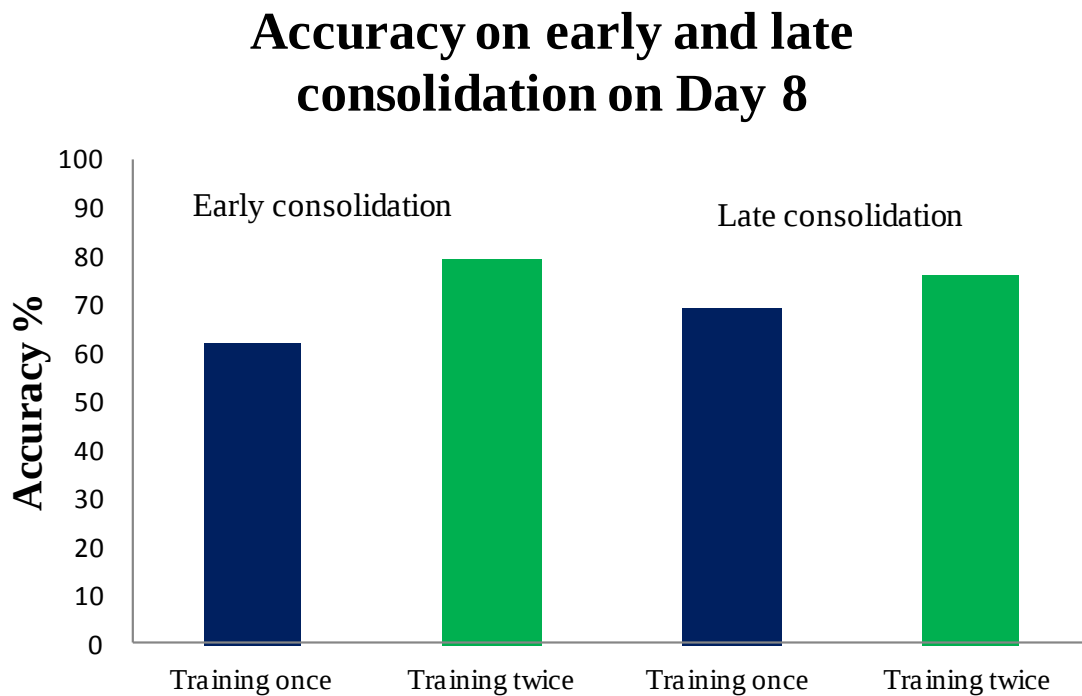


Figure 8 Accuracy on early and late consolidation on day 8

Chapter 5- Discussion, Conclusions and Limitations

5.1 Discussion

The current study attempted to shed light on the role of sleep in the consolidation of English novel words corresponding to living and nonliving concrete nouns. It also dealt with the influence of frequency of exposure in the learning of novel words in a foreign language. Contrary to one of our hypotheses, the results obtained from the semantic categorization task showed that participants' performance seemingly did not benefit from a full night's sleep on the set of words learned under the sleep condition; however, the thoroughly analyzed results account for a long lasting and pervasive effect of sleep on word consolidation few days after initial exposure.

Sleep

The experiment collected data from a semantic categorization task that measured accuracy and reaction time (RT). On the first testing session (day 2) accuracy levels did not show a significant difference between the words that were learned previous to a full night's sleep and the words that were learned immediately before testing. This result indicates that our hypothesis cannot be confirmed because the sleep variable did not improve accuracy compared to the non-sleep condition. Nevertheless, we cannot suggest that sleep did not help at all, instead, the higher results obtained from the non-sleep condition may be due to another factor that we did not control properly (recency effect). This effect stands for the high probability of recalling observed for items rehearsed just prior to testing. In other words, when people are asked to recall in any order items from a list, those that come at the end of it are more likely to be successfully recalled (Rundus & Atkinson, 1970). The fact that the testing session took place immediately after the second training session without any interfering task may have been the factor that boosted the recall of non-consolidated words.

In terms of reaction time (RT) measures, the results are significant in favor of the non-sleep condition which suggests that responses corresponding to the words that participants learned previous to a full night's sleep were categorized more slowly than the ones learned

immediately before testing (day 2). This phenomenon may be attributed to the direct retrieval of non-consolidated lexical items from short-term memory, which is accessed immediately and even faster than memory traces stored in long-term memory not usually recalled (Cave, 1992). The faster recall of non-consolidated words might correspond to a residual effect triggered by the short amount of time provided between exposure and testing sessions (Bo, Jennett & Seidler, 2011).

The main difference between our results and previous studies suggesting that a night's sleep, or even a nap, induces dramatic changes in the way novel words are represented in the brain and contributes to the dynamics of language processing (Dumay & Gaskell, 2012), is that our measures were to a certain extent interfered by the recency effect generated by the design of the experiment, hence we could not assume that sleep does not have an effect on learning words in a foreign language.

Sleep effect overtime

Eight days after initial exposure participants took part of a second testing session where accuracy and reaction time measures showed the state of consolidation overtime for the sleep and non-sleep condition, taking into account that after 8 days, all participants have had several full nights' sleep; therefore, there must have been some sort of effect coming from offline consolidation on the learning of the twenty novel words in English we presented. Accuracy results indicate that both conditions tend to even out 8 days after. This ultimately suggests that the fleeting effect of recency that affected the results of the first testing session no longer boosted correct responses coming from recently learned words performed on the test.

As discussed in Dumay and Gaskell (2010) sleep itself does not prevent lexico-semantic stimulation and processing (Bastuji, Perrin, & Garcia-Larrea, 2002), but it may offer a scenario where the merely poverty of linguistic input (and thus interference) that normally characterizes it provides the necessary downtime for consolidation. What is more, the accuracy obtained from the sleep condition remained identical 8 days after, in spite of the passing of time. The fact that the sleep condition results did not improve nor did decrease over

time, accounts for the long- lasting and stable effect that consolidation provides to newly acquired words. Stickgold and Walker (2005) agree on the point that once words are consolidated they become stable and remain resistant to degradation in long-term memory even for long periods of time.

Regarding reaction time (RT), there was not a statically significant difference between day 2 and day 8 inclined towards the sleep condition, what is more, responses were almost identical despite the passing of time which is consistent with previous findings supporting the idea that consolidation produces long lasting effects over a long period of time (McGaugh, 2000). On the contrary, the non-sleep condition words were categorized significantly more slowly on day 8 than on day 2 yet, the reaction time measures were similar to the ones obtained by the sleep condition words on day 8. This might be explained by the interplay of recency as a non-controlled variable. Recency transitory boosted a faster reaction time in words learned just before the first testing session; nevertheless, such effect disappeared by the second testing session on day 8 probably as a result of retrieving memory traces from long-term memory. A faster recall of non-consolidated words on day 2, but not on day 8, is congruent with the view that declarative memory traces are faster recalled from short-term memory in comparison to retrieval from long-term memory (Chiras, 2013).

Early consolidation vs. late consolidation

When analyzing the effects of consolidation within the same conditions, it is worth mentioning the main difference between both. Early consolidation stands for words learned prior to a full night's sleep before testing, therefore consolidated, whereas late consolidation refers to words learned right before testing, therefore not consolidated through sleep. In the case of this study, early consolidation words obtained the same accuracy percentages on every testing session (day 2 and 8) as both times they were tested as words that had undergone offline consolidation, as opposed to the late consolidation words that had not undergone offline consolidation by the time they were tested for the first time (day 2). Late consolidation accuracy dropped considerably by day 8 as by the second testing session they became words

consolidated through sleep, reaching the same accuracy of the early consolidation words on day 8. The similar and stable accuracy of consolidated words hints that once the process of consolidation stabilizes, a newly learned word remains stored for long periods of time if no new retroactive interference tampers nor further exposure strengthens its neural representation (Deliens et al., 2013).

The comparison within the same conditions respecting reaction time (RT) showed that the time of responses were significantly faster on day 8 for the early consolidation words compared with day 2. Similar results were obtained from the late consolidation words showing faster responses on day 8 in comparison with those obtained on day 2. Davis, Betta, Macdonald and Gaskell (2009) have looked closely into the consolidation of novel spoken words from a neuroscientific approach. In an experiment carried out by using fMRI scans, they found evidence that may explain why the recalling of consolidated words is faster in comparison to non-consolidated words. As consolidated words are stored in the neocortical regions of the brain, they can be recalled faster and more efficiently than memory traces temporarily stored in the hippocampal regions due to recent exposure and non-consolidation. Consolidation strengthens neural representations such that newly learned words can be recognized more rapidly hence, compete in retrieval with existing words. The fact that the word categorization is faster 8 days after has to do with an in-progress strengthen of neural networks (containing novel words) as a result of neuroplastic changes in the brain (Tse et al., 2001). Although the findings previously mentioned focused on the learning of words in a first language, our results suggest that a similar phenomenon affects learning words in a foreign language since the semantic neural activation lower than N400 is triggered by any sort of linguistic input containing a meaningful message regardless the language (Curran, Kutas & Posner, 1993).

Frequency of exposure

The variable of frequency of exposure affecting the participants' performance was the last hypothesis we formulated. Frequency of exposure in the form of single and double

training sessions had an interplay with the results as a two-sided variable. Accuracy was affected by how many times participants went through learning sessions, having as a result that consolidated and non-consolidated word sets were better recalled when acquired in two learning sessions, as opposed to lower recall in word sets learned only once. This may be explained by previous findings that support the assumption that long-term storage depends on the number of rehearsals given to an item. This agrees with neural evidence that has suggested that the more times a novel word is exposed, the higher the brain activity will be in the prefrontal and left temporal regions engaged during semantic processing therefore, there is a correlation between higher recognition of words and training-related changes in brain activity (Atkinson, Richard & Shiffrin, 1971; Kirchhoff, Anderson, Barch & Jacoby, 2012).

Even though the results obtained from the analysis of this variable did not show a statistically significant difference between the groups, it is indeed enlightening to notice that in every single test the double training session group surpassed the results obtained by their single training session counterparts even 8 days after initial exposure to the stimuli.

5.2 Conclusions and limitations

5.2.1 Conclusions

According to the results obtained in our study, it can be concluded that sleep has a similar effect on the consolidation of novel words in a foreign language as it does in the consolidation of novel words in a first language. Sleep contributes to the consolidation of memory traces and the transfer of foreign novel words from short-term memory to long-term memory allowing the categorization of newly learned words to be stable and long lasting.

Although our results did not show sleep to be beneficial after a single full night's sleep due to the design of the experiment, it showed a stable effect of consolidation over time and faster recognition of semantic categories presumably given by the strengthening of neural representations of words in the neocortical regions of the brain making the categorization of them more efficient. The efficiency on the categorization of novel words into living and non-living items just mentioned was also improved by the frequency of exposure to the stimuli which was an additional variable included in the design that hints that the more a stimulus is exposed, the better it will be recalled.

Such findings are important for EFL teachers since the three-sided triangle of teaching that is to say teaching, learning and testing may be benefited from actual insight coming from neuroscience. First, there are biological constraints about the learning brain when it comes to acquiring declarative and procedural knowledge, the fact that new memory traces are not automatically transferred as stabilized content compels teachers to review and recycle new information until there is proof that the learners have acquired the new memory traces in the long term. Second, as it was explained in previous chapters, the passing of time seemingly strengthens neural representation of information and abilities stored in the long-term memory, that finding not only suggests a biologically automatized ongoing learning but also a time-window that must be considered when it comes to testing purposes. The ultimate advice for teaching matters would be to await a minimum span of time ranging from days to weeks before assessing the acquisition of newly learned words in the case of vocabulary acquisition, or writing abilities in the case of assessing foreign language-related tasks. Third, although not

being the focus of this research, it is interesting to have obtained a consistent numerical tendency that reinforces the belief that training improves performance when it comes to learning.

Finally, it is worth mentioning that learning a second language, specifically second language vocabulary, involves much more than methodological techniques. Although teaching strategies' effectiveness has been proved, biological aspects do affect and contribute to learning. Cognitive processes underlying learning are primary based on neuroplastic changes regulated automatically and programmed genetically, that is why an increasing awareness about the basics of brain functioning should not be overlooked by EFL learners and teachers.

5.2.2 Limitations of the study

Some limitations affected the results of our study and may have prevented us from observing some of the phenomena we expected and anticipated in our hypotheses. The first one was the lack of time we provided our participants in between the second learning session and the first testing session that took place on day 2. The fact that the testing session took place right after participants were exposed to the stimuli triggered a transitory boost in non-consolidated words corresponding to the non-sleep condition which ended up in the semantic categorization test documenting a recency effect. Other studies have dealt with recency through test takers executing unrelated tasks in between learning and testing sessions; nevertheless, we were not aware of this when designing our experiment. The results on day 2, although accurate, do not represent the real effect of consolidation mediated by a non-sleep condition.

The second limitation was the short number of participants that took part in our experiment which led to having not enough statistical power to reach statistical significance in some results. In psychology research, twenty participants is usually enough to support any hypothesis however, our study was affected by not having a bigger sample especially in the analysis of participants' performance when divided into single and double-training groups when in spite of having a clear tendency from the double-training group to always outperform the single-training group, the results obtained did not reach statistical significance.

It is advisable to consider the limitations just mentioned in future replications of this experiment since they could be easily overcome by following simple strategies such as including as many participants as it is possible in order to reduce the standard deviation and increase significance and, whenever a test reliability relies on accurate measures of memory recall or categorization, it is unavoidable to clear subjects' short-term memory or working memory by making participants perform unrelated tasks or long breaks prior testing sessions since such details existing in the design of the experiment prevented us from getting representative effects of word consolidation.

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Appendices

Appendix 3.1

List of nouns divided into living and nonliving

Living nouns

Peadle

Clamod

Wrast

Smank

Hendor

Kentor

Chapice

Shent

Glaw

Dism

Nonliving nouns

Dather

Slamen

Gonar

Pauve

Shoug

Wrecber

Sernal

Ramrod

Krauf

Calt

Appendix 3.2

List of nouns divided into two sets of 10 each, in which 5 living words and 5 non-living words were included

Set A

Living	Clamod
--------	--------

Living	Peadle
--------	--------

Living	Wrast
--------	-------

Living	Smank
--------	-------

Living	Hendor
--------	--------

Non-living	Dather
------------	--------

Non-living	Slamen
------------	--------

Non-living	Gonar
------------	-------

Non-living	Pauve
------------	-------

Non-living	Shoug
------------	-------

Set B

Living	Kentor
Living	Chapice
Living	Shent
Living	Glaw
Living	Dism
Non-living	Wrecber
Non-living	Sernal
Non-living	Ramrud
Non-living	Krauf
Non-living	Calt

Appendix 3.3



The sernal was discovered in Crete by an Italian archaeologist.



The sernal dates back to the second millenium (B.C.E) and was probably used as a syllabary or an alphabet.



The sernal's symbols represent people, tools, plants, and animals.



The sernal is made of clay and is covered with stamped symbols.



The sernal is a unique item of no more than 15 cm in diameter.

Appendix 3.4



The sarnal is a unique item of no more than 15 cm in diameter.



The sarnal was discovered in Crete by an Italian archaeologist.



The sarnal dates back to the second millenium (B.C.E) and was probably used as a syllabary or an alphabet.



What is the sarnal used for?

|

Correct answer:

As a syllabary or alphabet

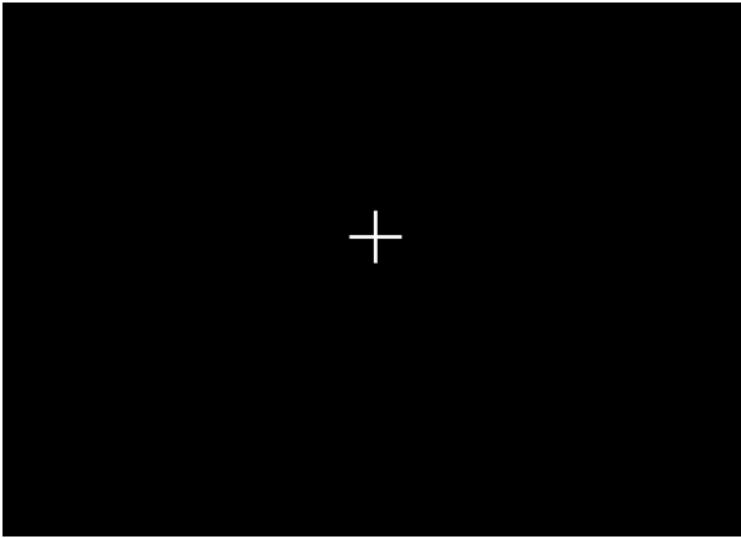
Appendix 3.5



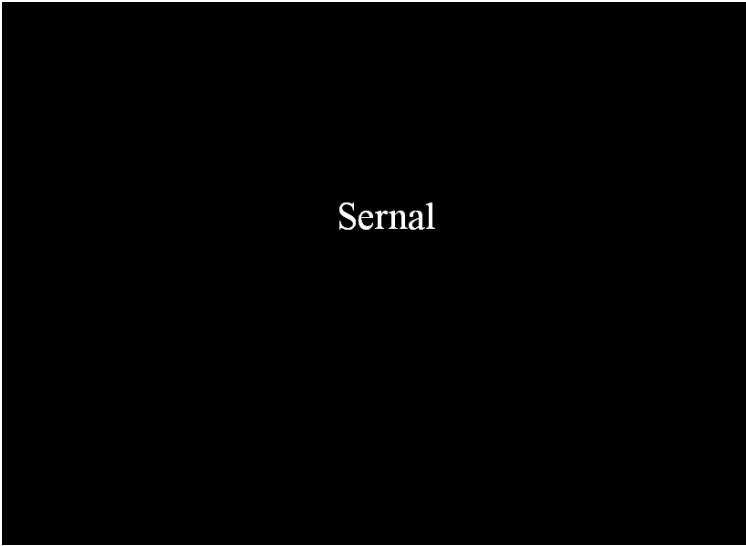
Sernal

I

Appendix 3.6



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Sernal